

Optical Coatings and Surfaces in Space: MISSE

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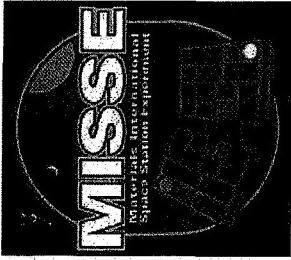
Environmental Effects Group

Mail Code EM50 Bldg. 4711 Room 100C

Marshall Space Flight Center, AL 35812

Abstract

The space environment presents some unique problems for optics. Components must be designed to survive variations in temperature, exposure to ultraviolet, particle radiation, atomic oxygen and contamination from the immediate environment. To determine the importance of these phenomena, a series of passive exposure experiments have been conducted which included, among others, the Long Duration Exposure Facility (LDEF, 1985- 1990), the Passive Optical Sample Assembly (POSA, 1996-1997) and most recently, the Materials on the International Space Station Experiment (MISSE, 2001-2005). The MISSE program benefited greatly from past experience so that at the conclusion of this 4 year mission, samples which remained intact were in remarkable condition. This study will review data from different aspects of this experiment with emphasis on optical properties and performance.

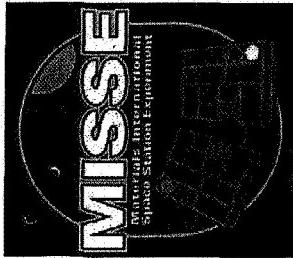


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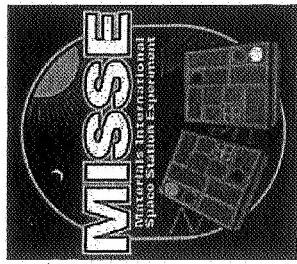
The MISSSE Flight Experiment

MISSSE - Materials on International Space Station Experiment

a project funded by AFRL and NASA

Project leads – Dr. Bill Kinard, NASA LARC
Dr. Gary Pippin, Boeing

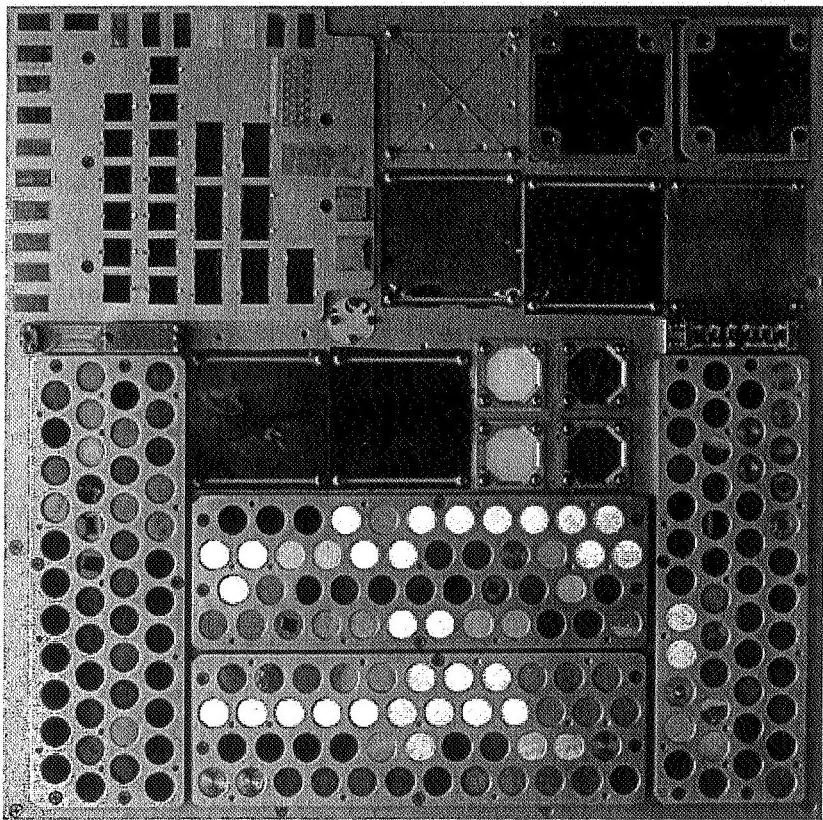
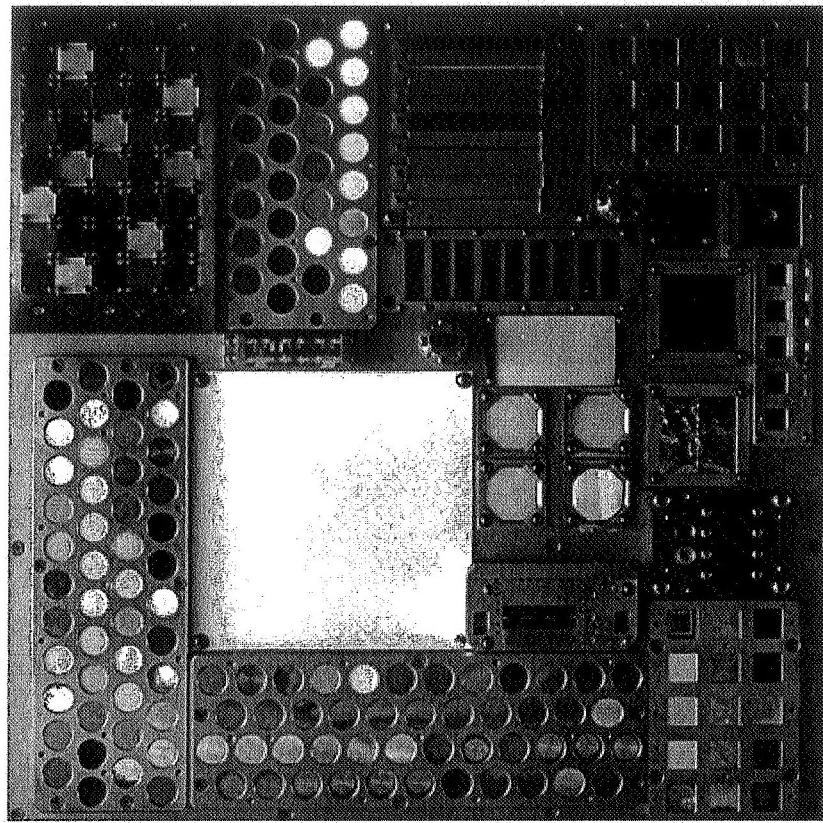
- Samples placed on station 8-10-01
- Recovery 7-30-05



MISSe trays Prior to Deployment

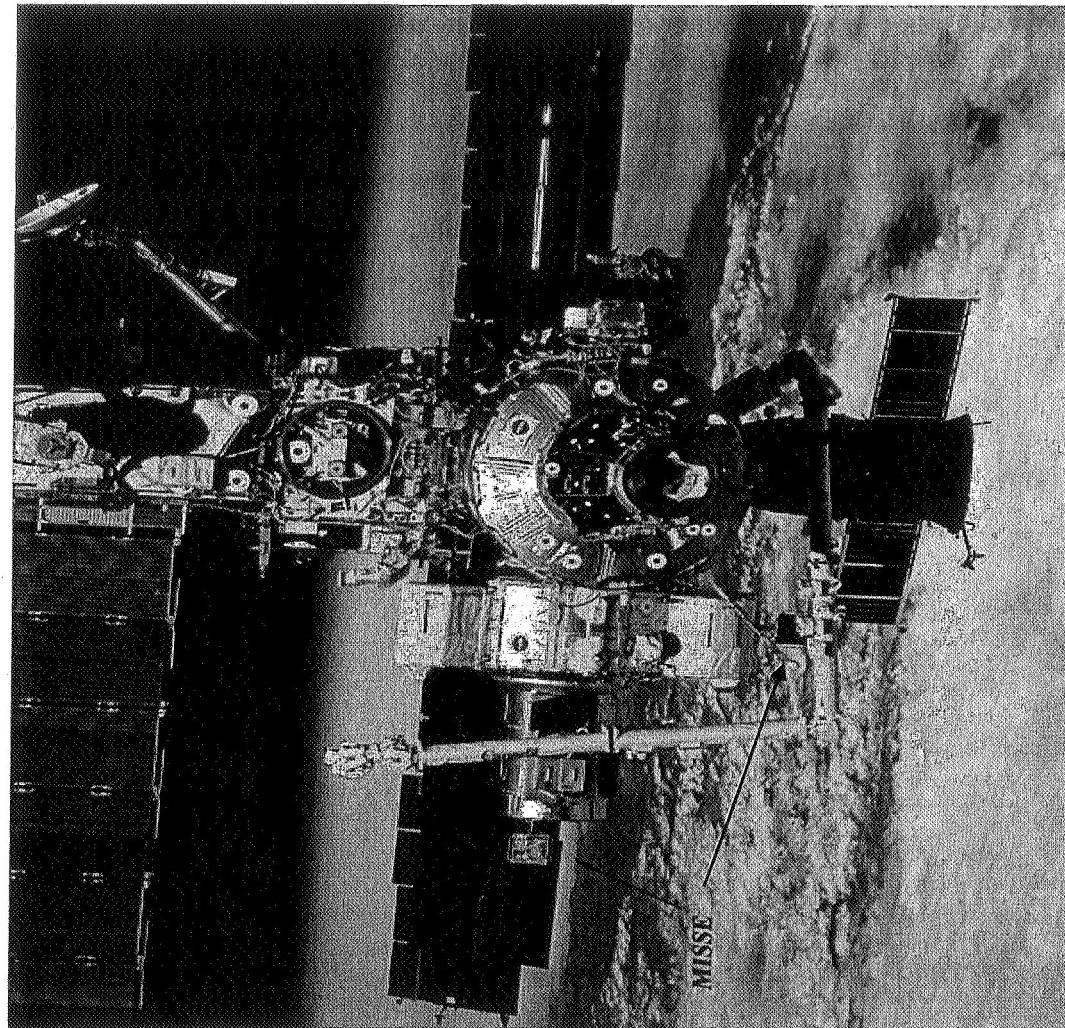
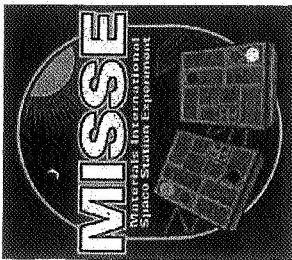
AO and Solar

Solar exposure



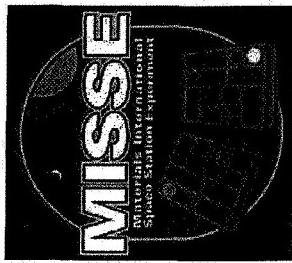
Passive experiment containers (PEC) DES

MISSE on the ISS



- Two Modules parked on the ISS for 3.9 years
- Two additional modules installed 7/06
 - 1 year exposure planned
- Locations selected for
 - min/max atomic oxygen
 - min/max solar
- EVA required for placement and retrieval
- Module integration at Boeing Seattle and Langley

Principal Mechanisms for Degradation of Optics in Space



Atomic oxygen

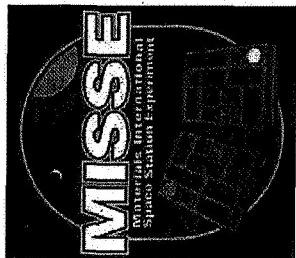
- 5 ev kinetic energy

Solar UV exposure

Radiation

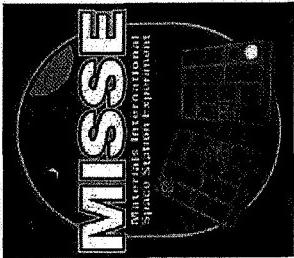
Micrometeoroids/Space Debris Contamination

- MISSSE designed to try to isolate/control AO and solar UV exposure
- Contamination limited by material selection and placement on ISS



Optical Coatings and Windows on MISSe

- >100 samples from about 10 groups
- a broad range of wavelengths and potential applications
- Objectives for all:
 - Define magnitude of degradation
 - Determine mechanisms for sample degradation
 - Define realistic performance expectations



MISSIE Samples : Coatings, Windows and Mirrors

Coating samples representative of solar cell covers, protected metals, precious metals, dielectric HR and AR designs

Thermal evaporation:

Lohnstar Optics

ZnSe, ThF₄, MgF₂, Al₂O₃

Sputtering:

MLD LLC, Litton Guidance

Si, SiO₂, Al₂O₃, Ta₂O₅, Nb₂O₅

Windows:

SiO₂, MgF₂

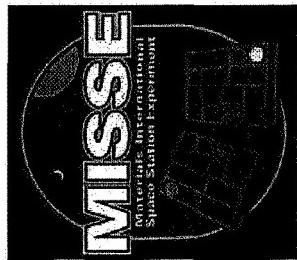
Metals:

AU, AI, Pt

Other:

Kaiser Optical

Dichromated gelatin



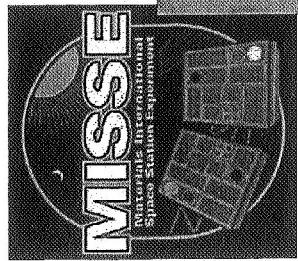
Evaluation Methods

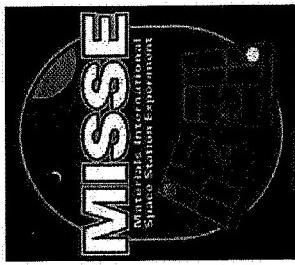
- ### Comparison of Flight Samples with controls
- Visual
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 - Spectral (spectrophotometer)
 - Absorption (laser calorimetry -IR and tc)
 - Total Loss (cavity ring-down)
 - Phase (ellipsometry)
 - Vacuum UV reflection
 - ESCA

Samples in Flight

August 2003
photoalbum

E4-32 and E4-33
Gyroscope optics





MISSSE Environments

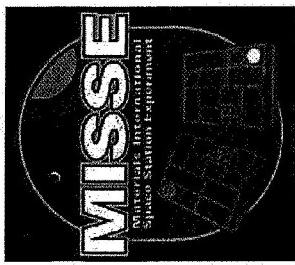
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~6°C variations for each orbit
a total range of -20 to +72°C

ISS provided some shielding from radiation (~1/4)



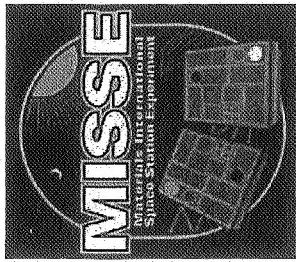
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- Clean work station
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- High purity DI water
- Spin cleaning station

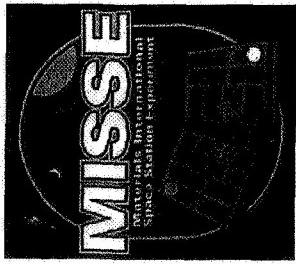
Flight Samples on the Bench



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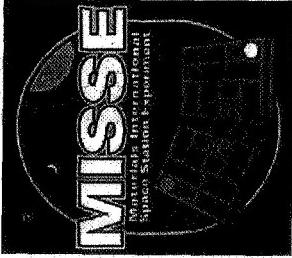
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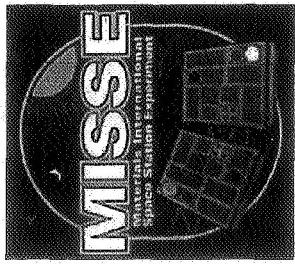
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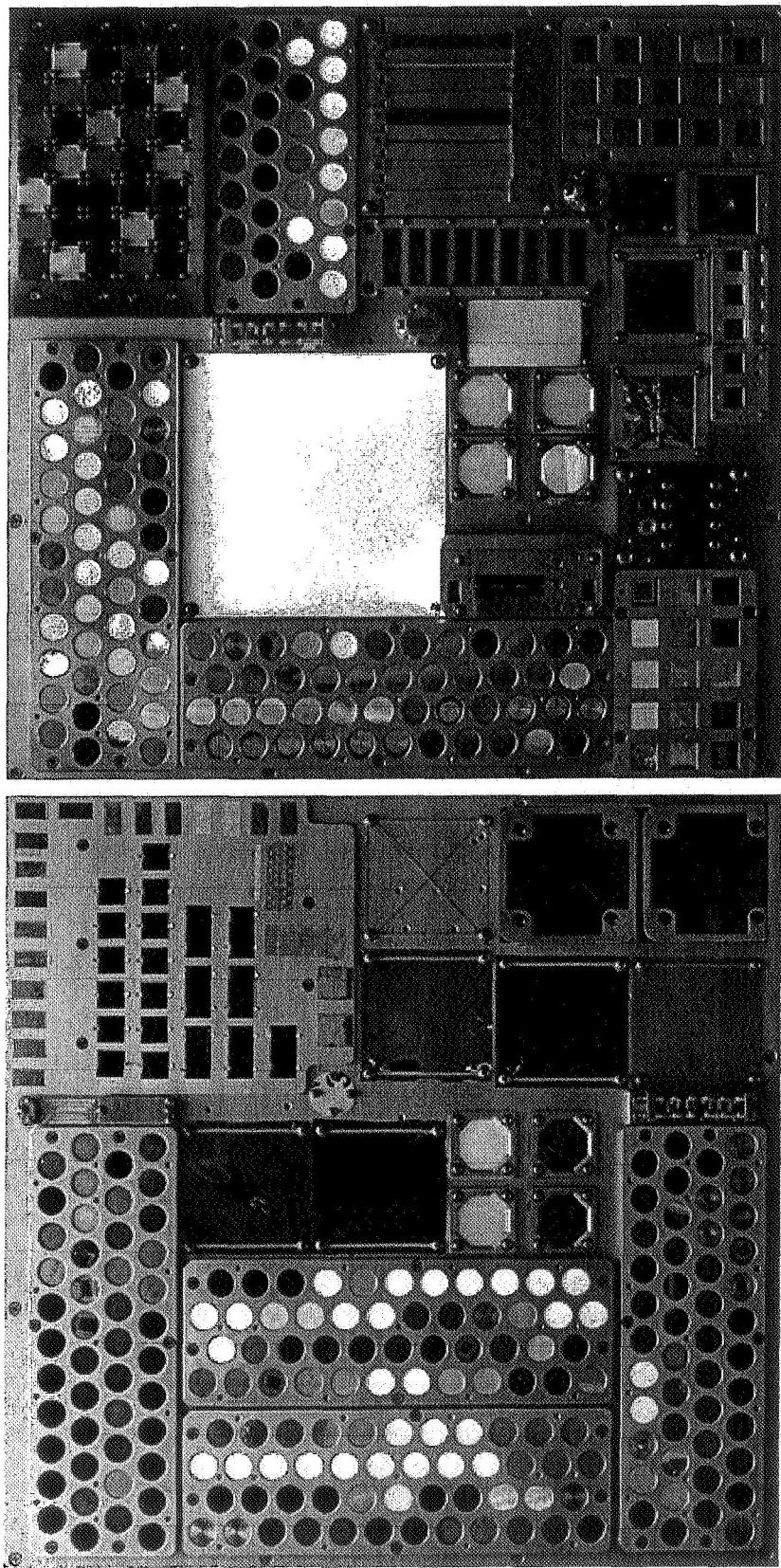
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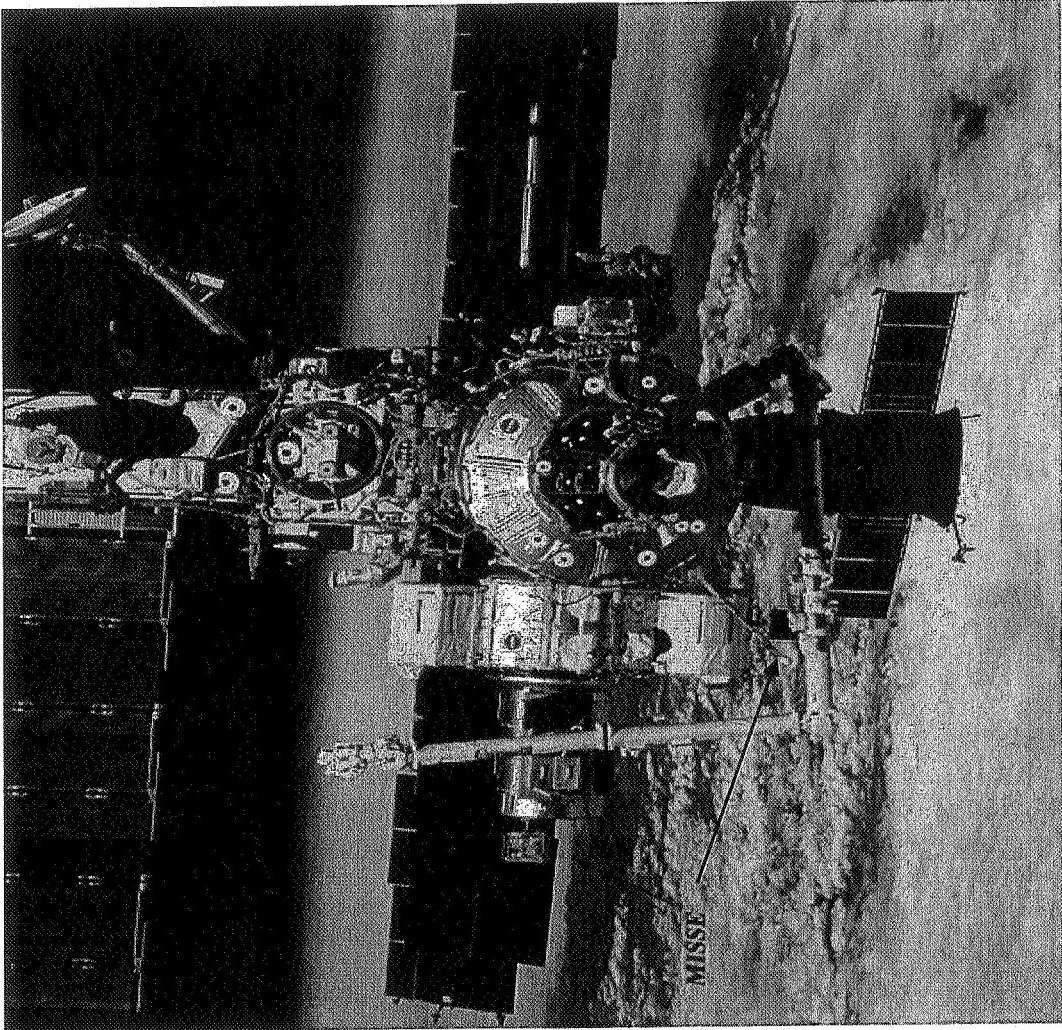
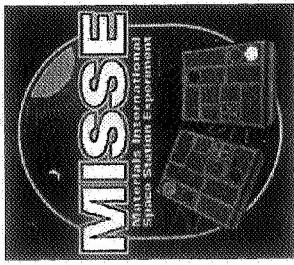
Solar exposure



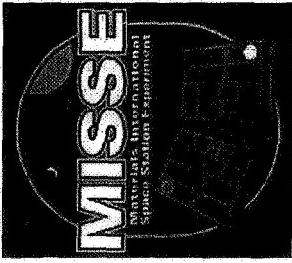
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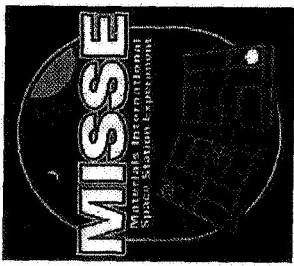
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Micrometeoroids/Space Debris

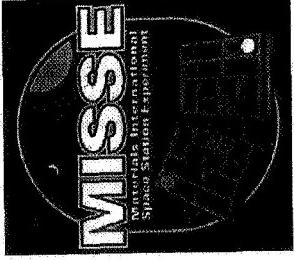
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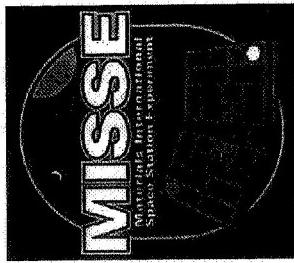
Sputtering:

Windows:

Metals:

Other:



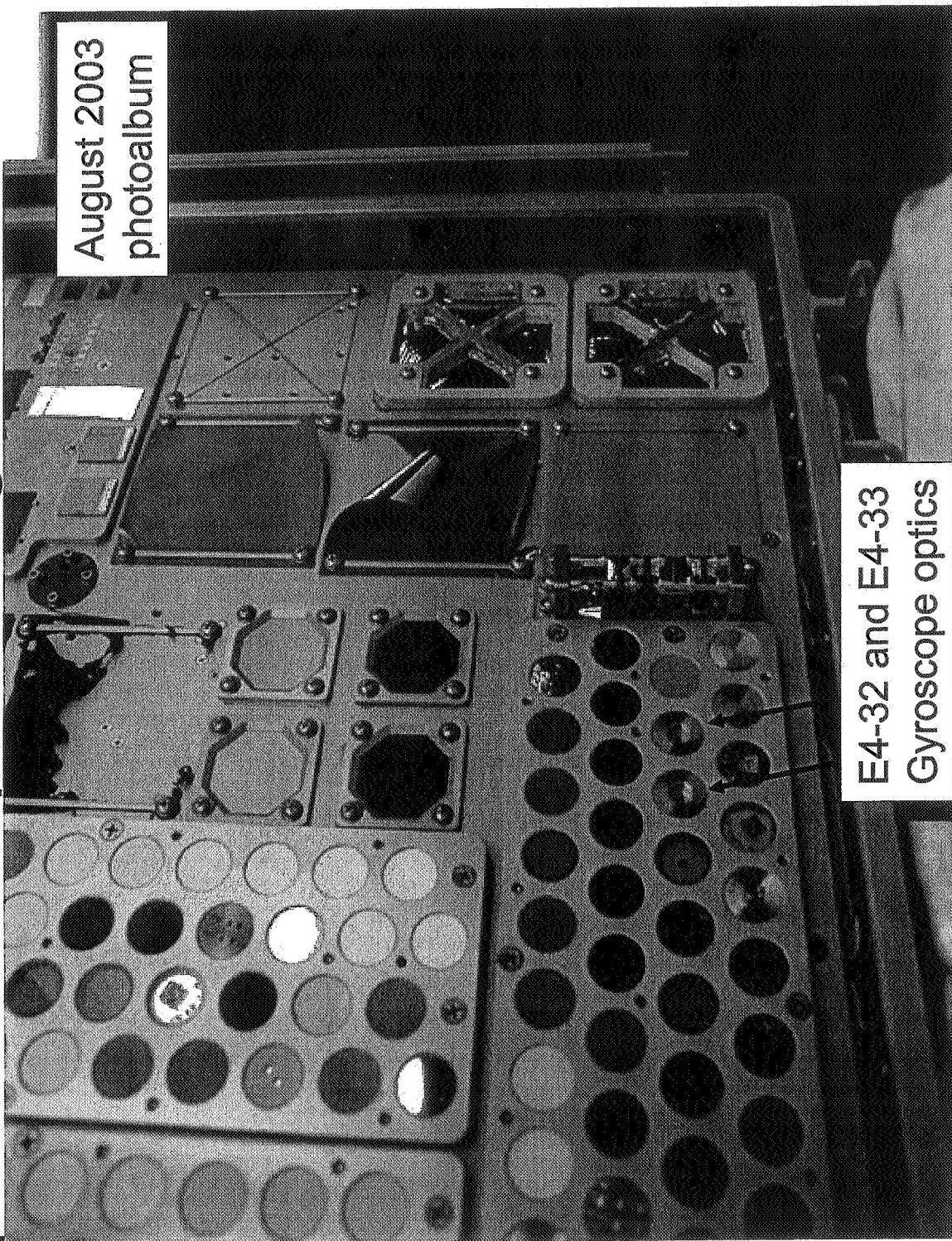


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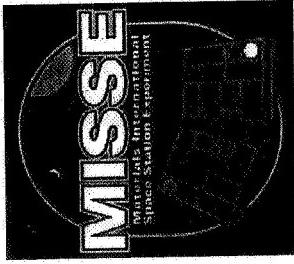


August 2003
photoalbum

E4-32 and E4-33
Gyroscope optics

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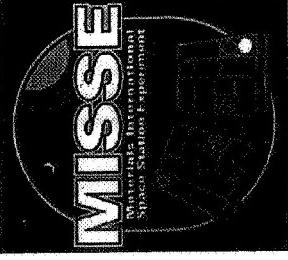
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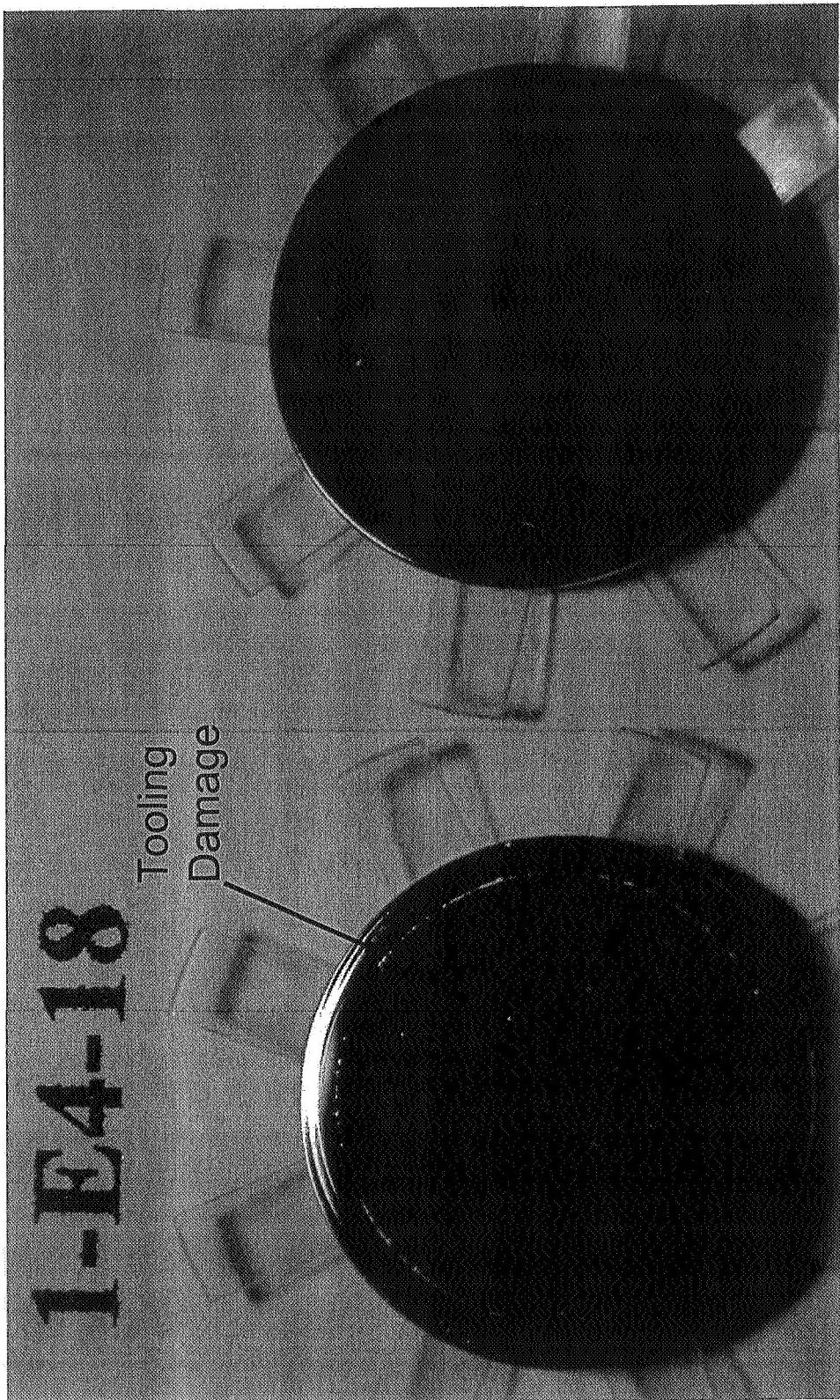
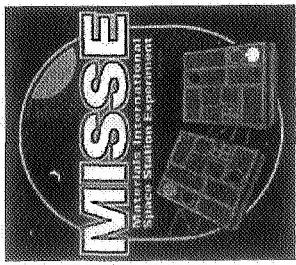
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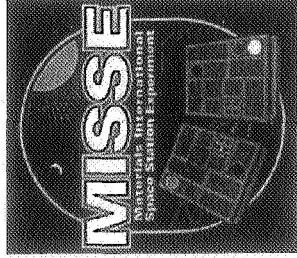
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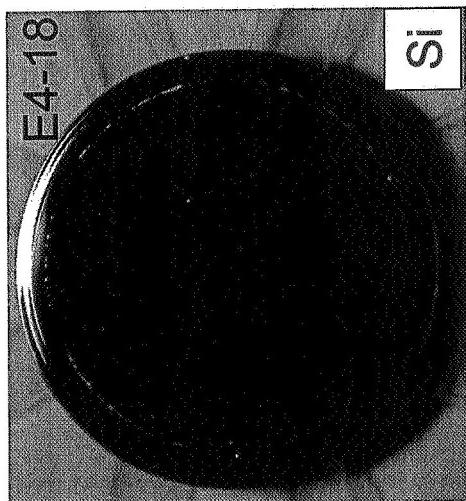
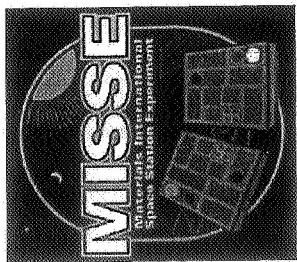


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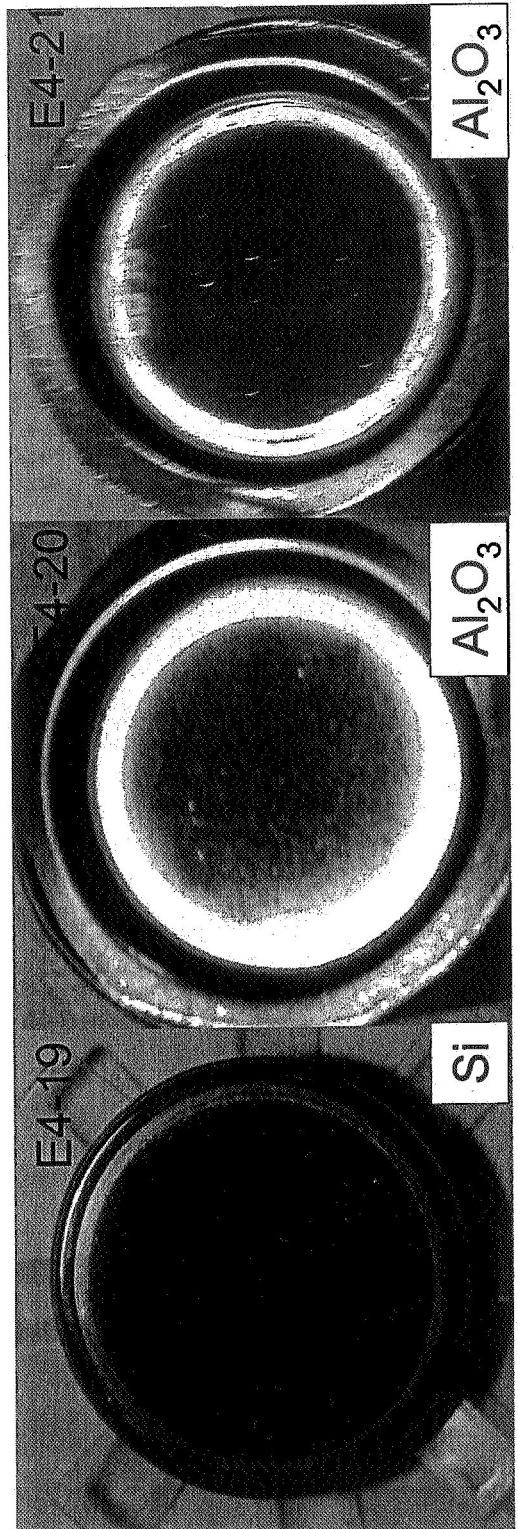
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ZnSe/ThF₄ Coatings on Silicon and Sapphire



ZnSe/ThF₄ stack with Al₂O₃ overcoat
Showing resistance to abrasion at
contact to sample mount and debris



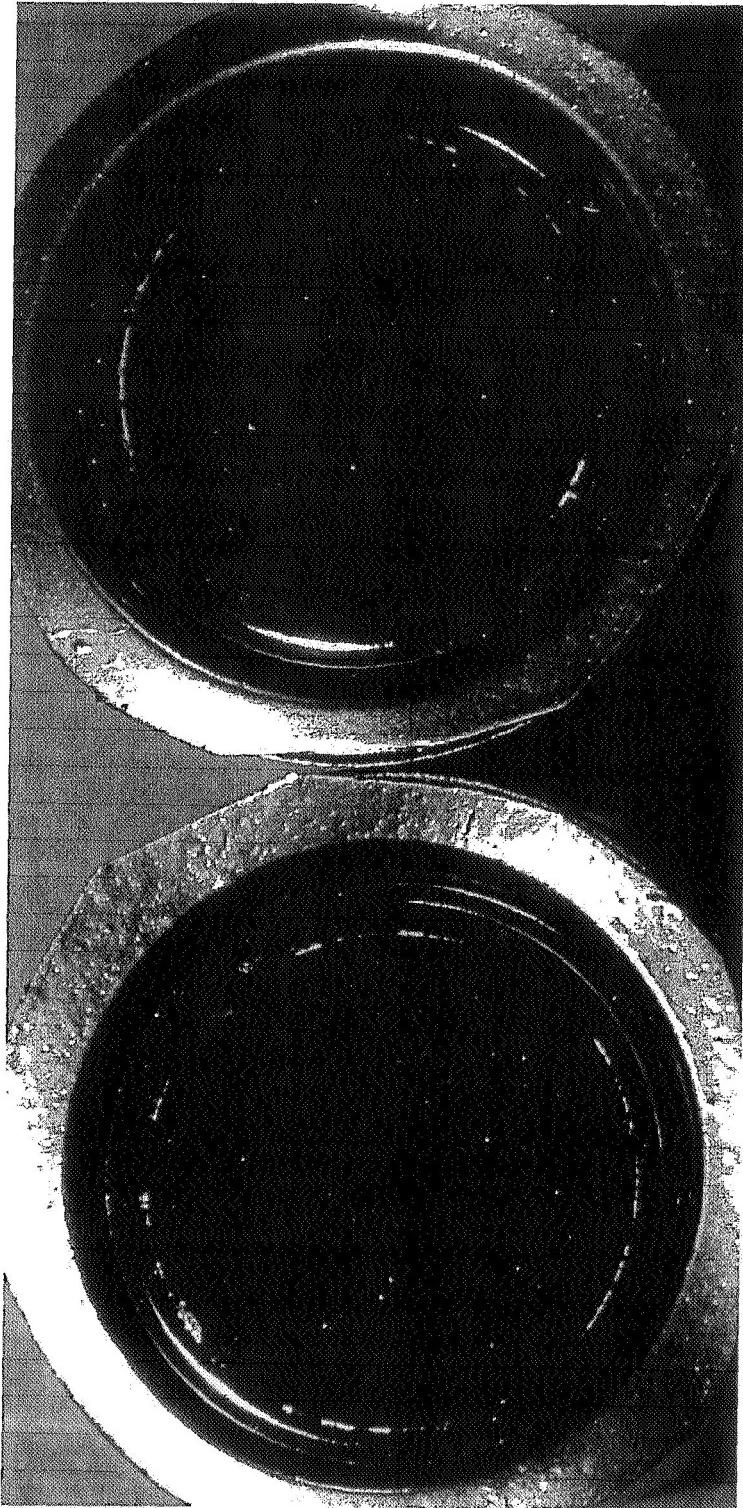
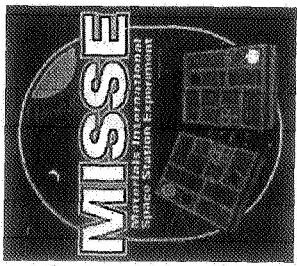
ZnSe/ThF₄ stacks showing abrasion at contact to sample mount and debris

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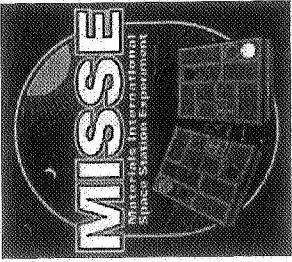
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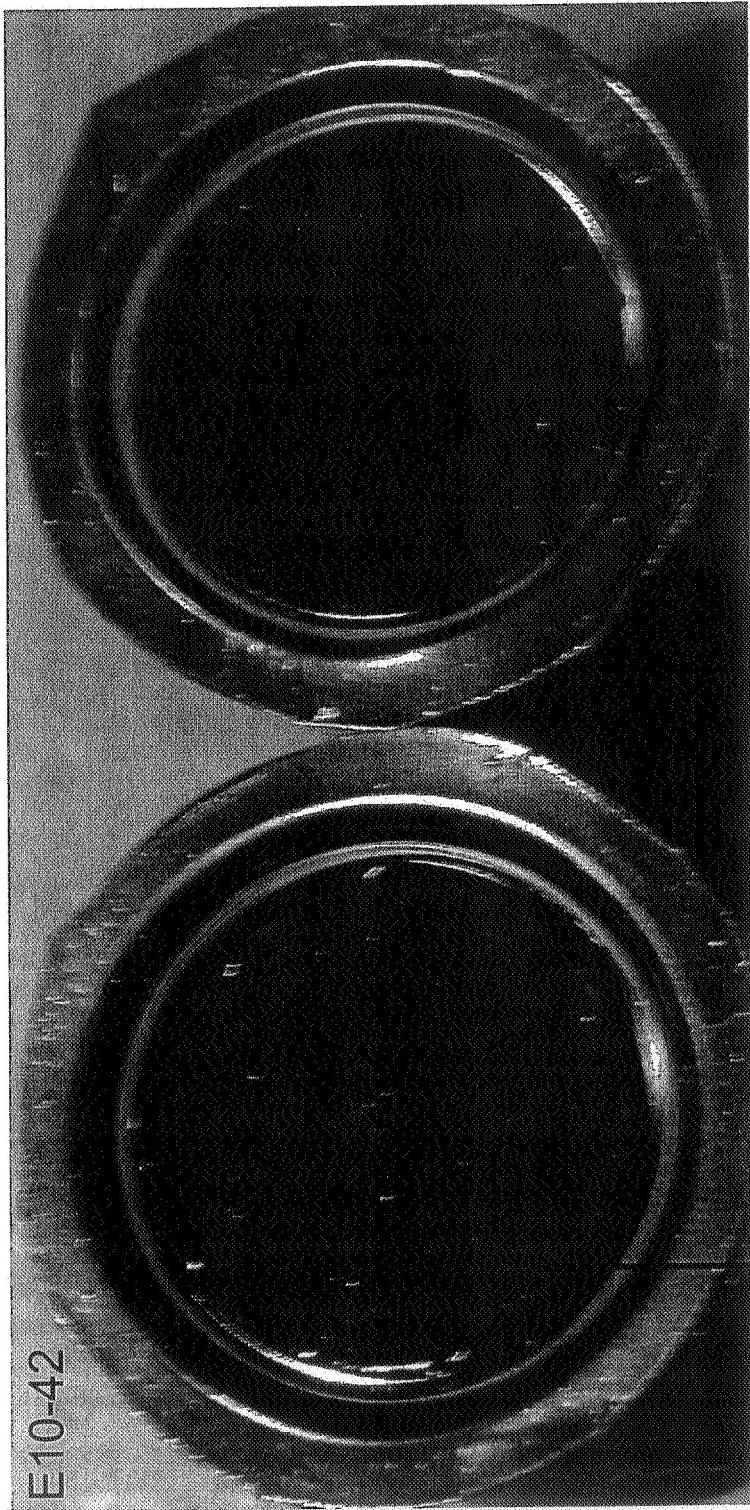
Si/Al₂O₃/SiO₂ Mirrors



Some tooling damage is evident in the contact area for the sample holder.

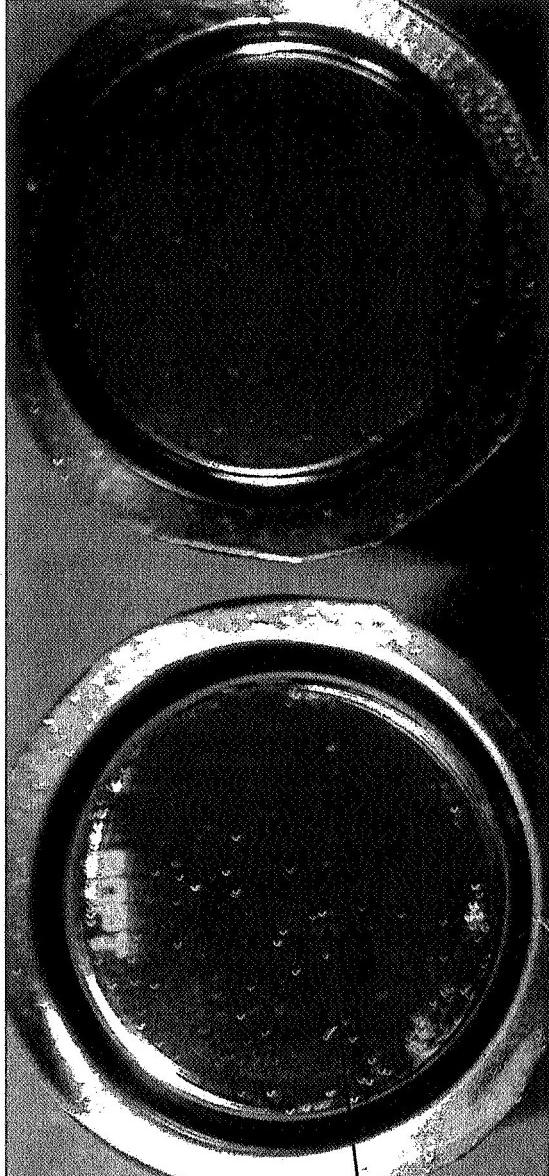
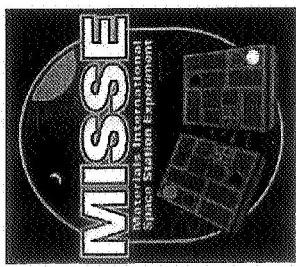


Si/Al₂O₃/SiO₂ Mirror Shows Contamination

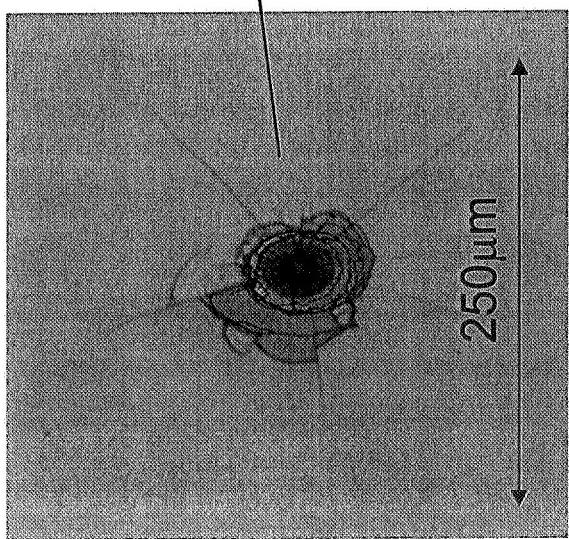


Contamination layer is lighter in color than unexposed coating

Micrometeorite Impact!



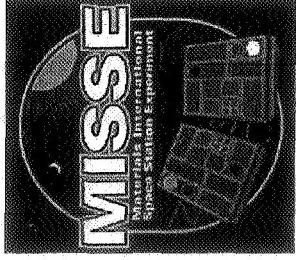
E10-41



ZnSe/ThF₄ coating on sapphire

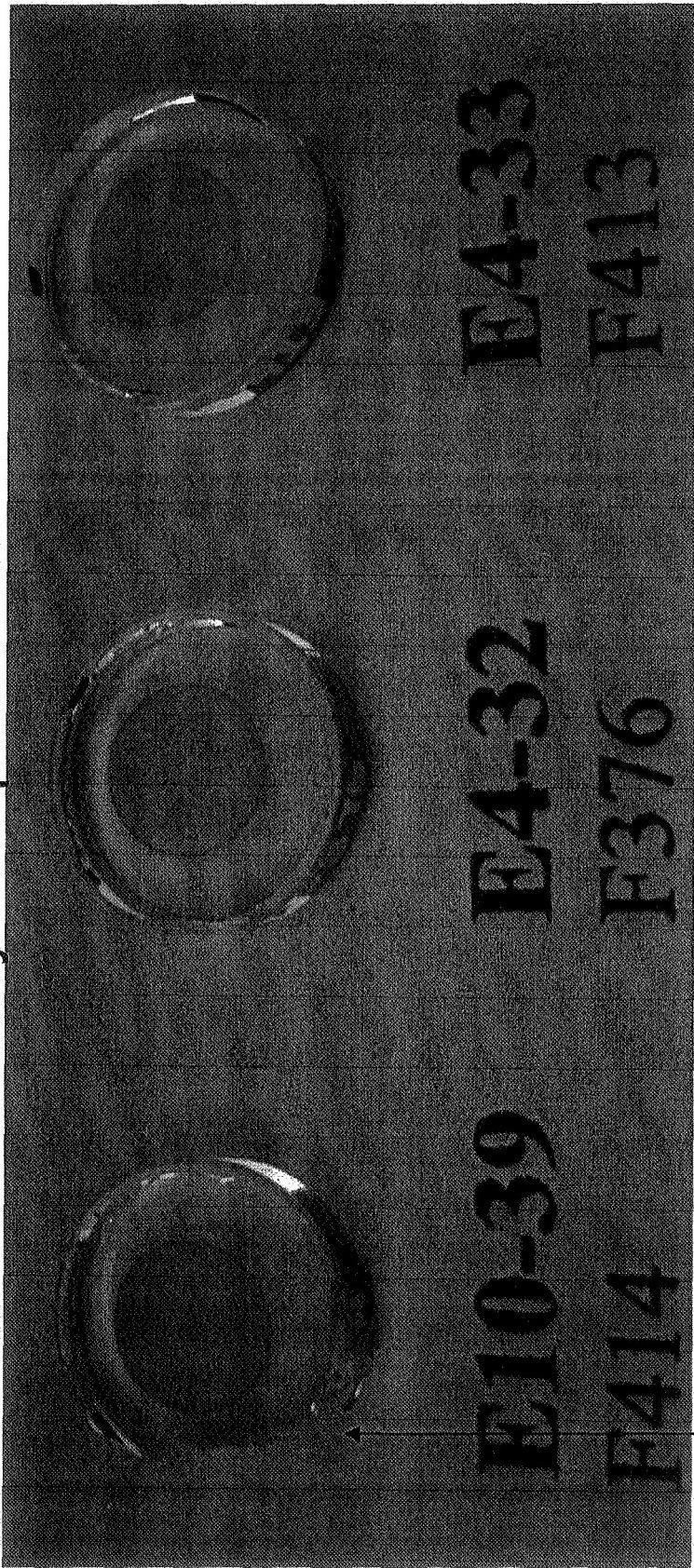
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Flight Samples on the Bench

Laser Gyroscope Mirrors

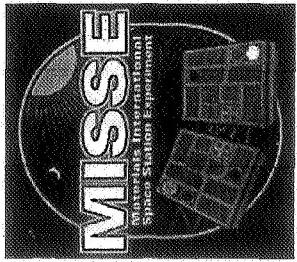


Serious tooling damage!

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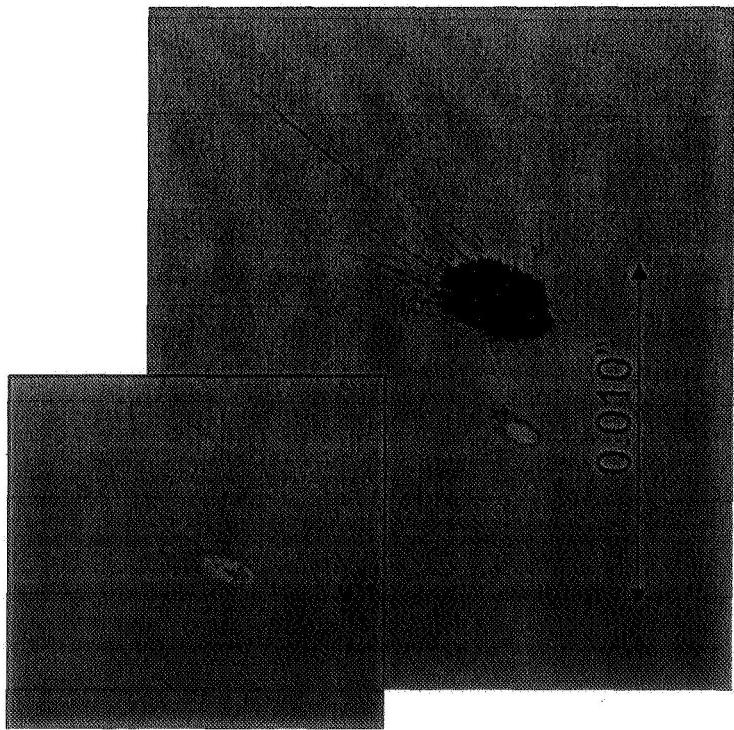
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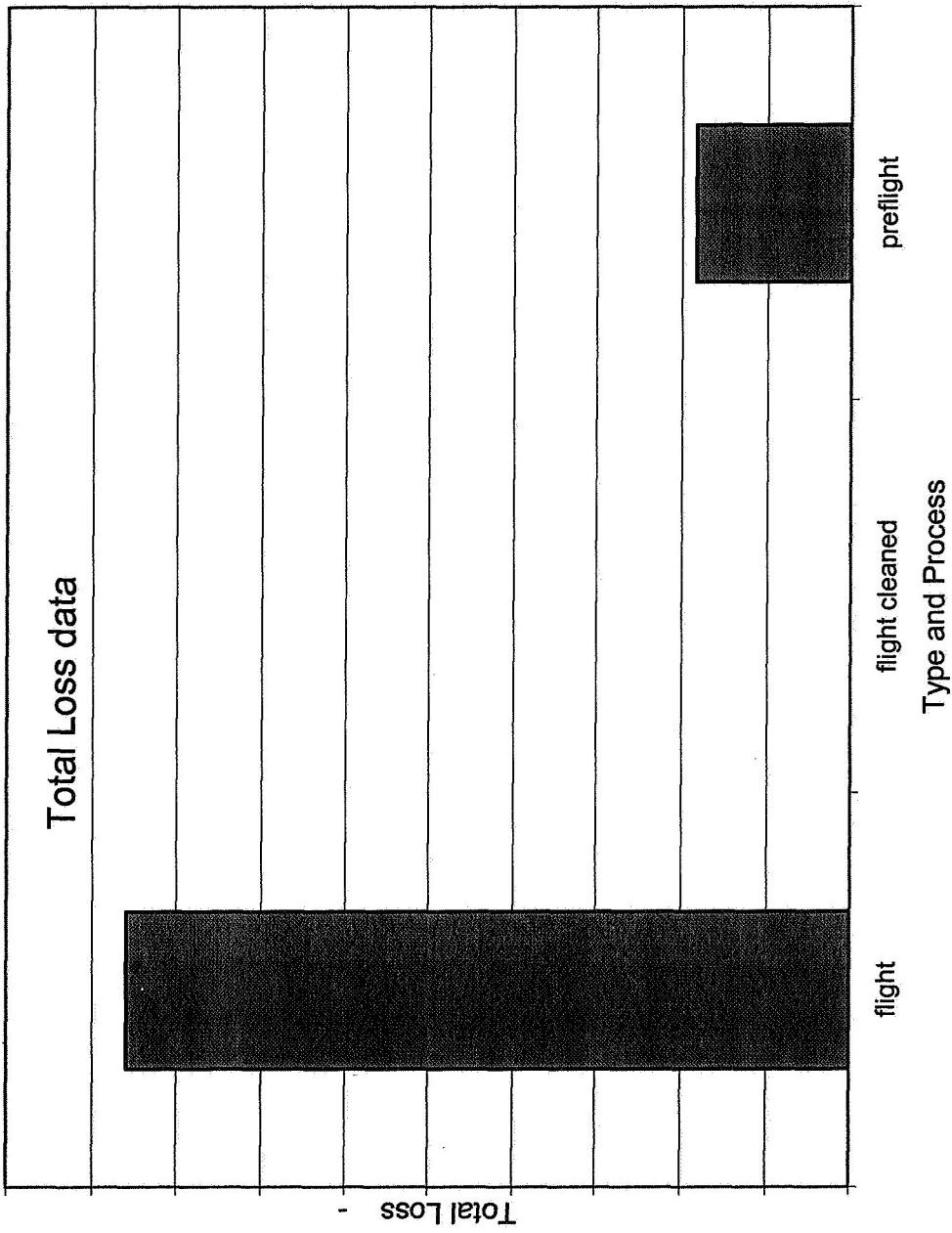
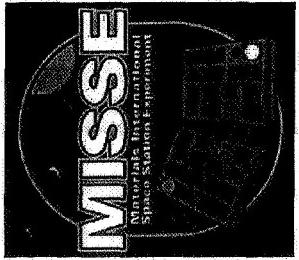


Laser Gyroscope Mirrors Showed "Liquid" Contamination

Surface contamination observed on
Flight samples showing:
Liquid nature of particle
Highly directional emission



633nm Laser Gyro Mirrors

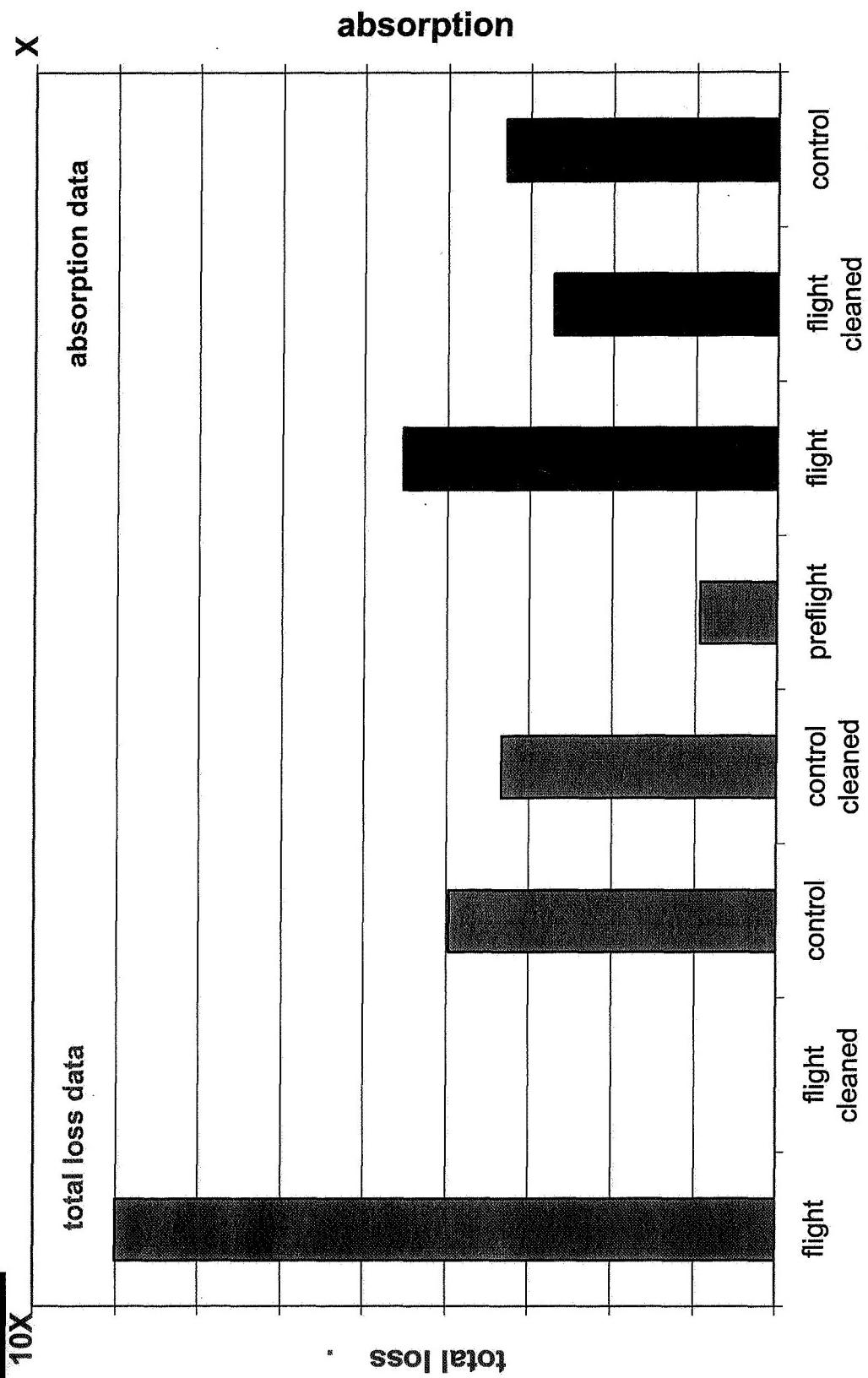
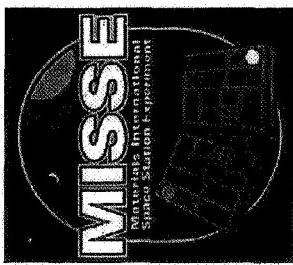


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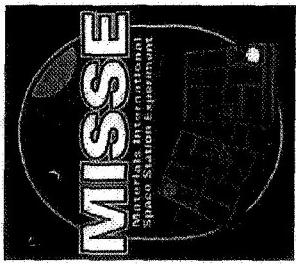
Total Loss and Calorimetry at 1319nm



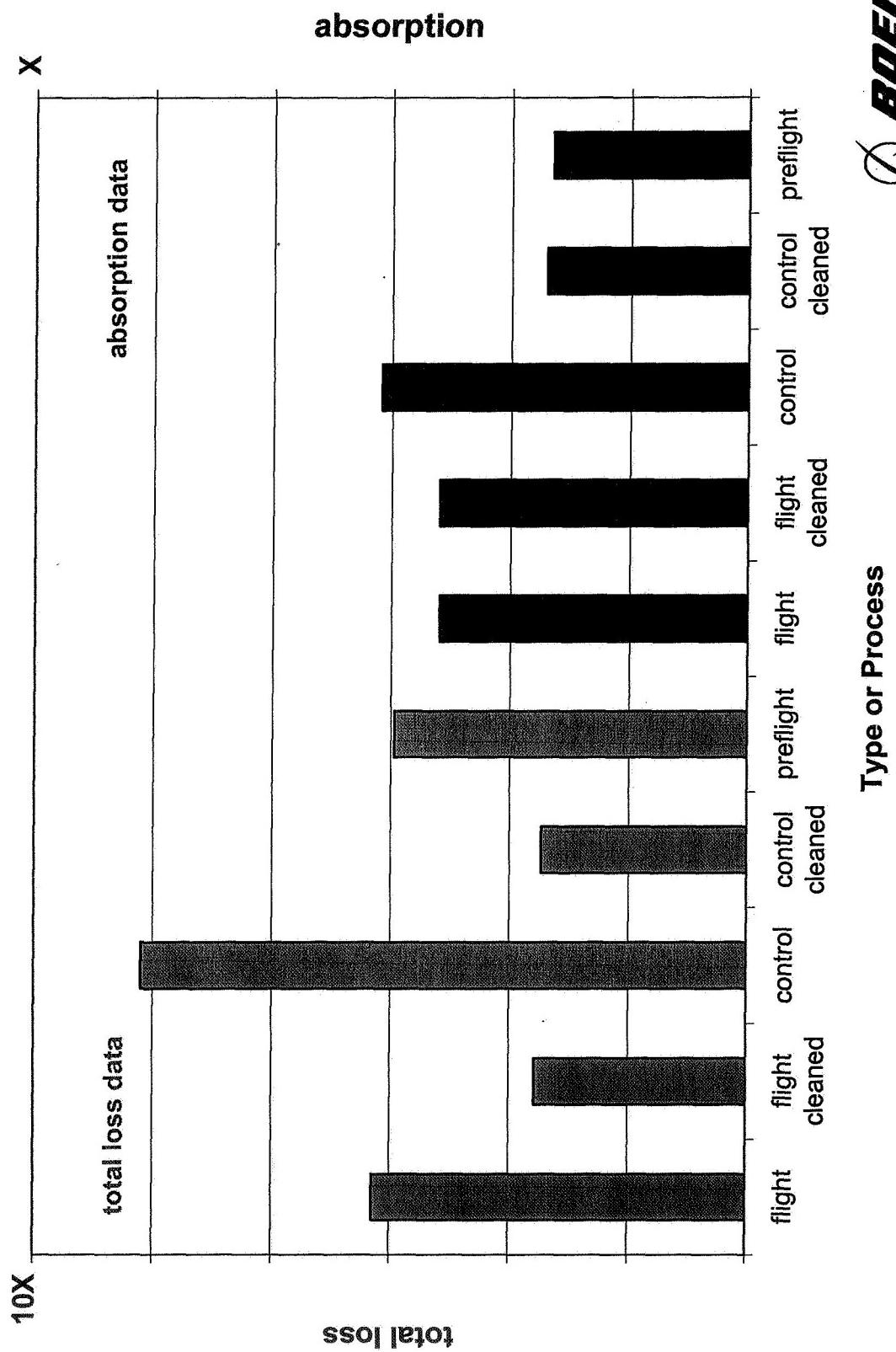
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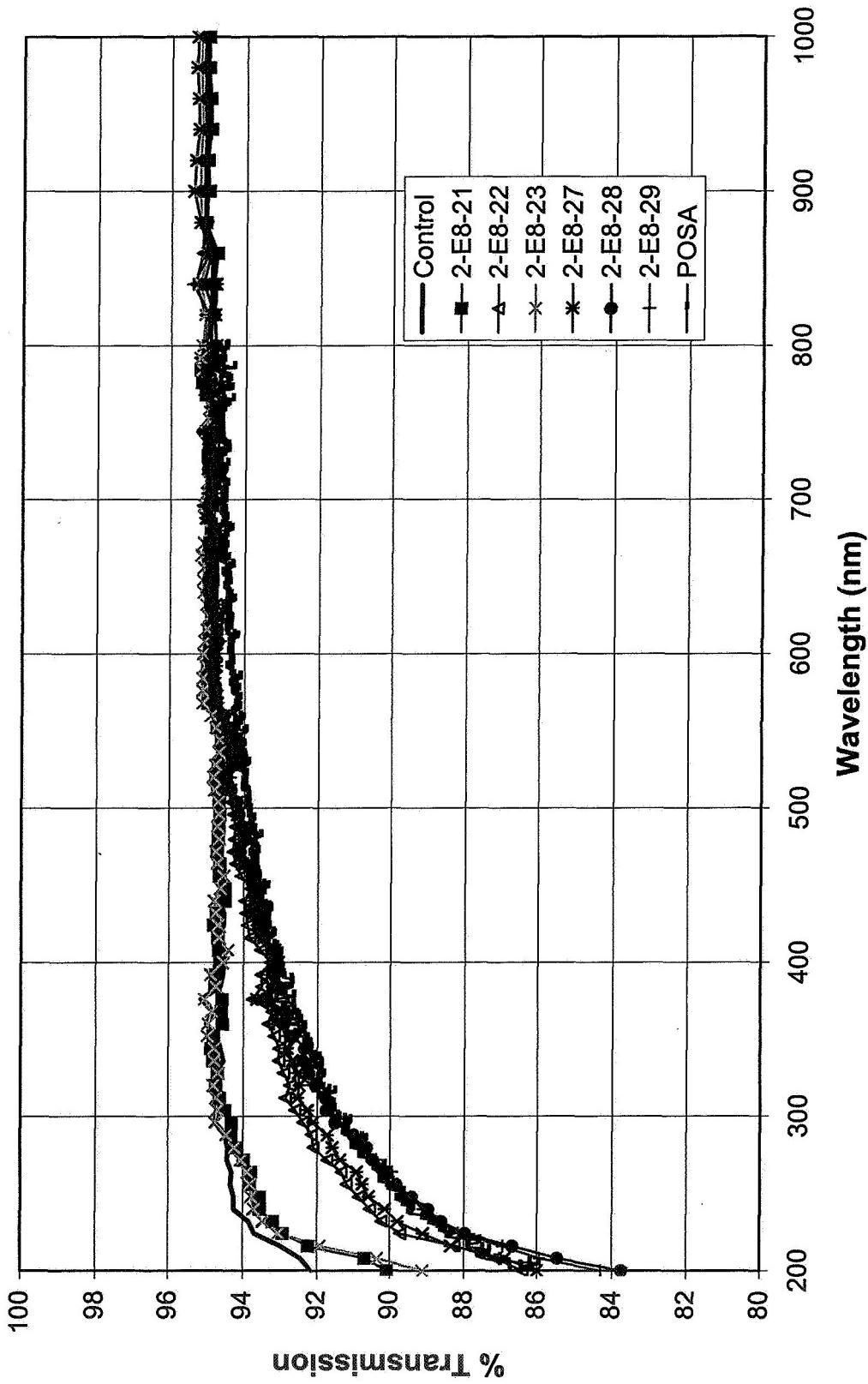
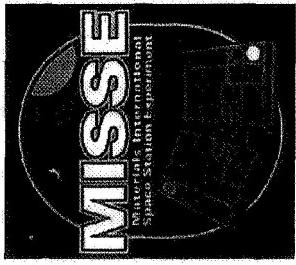
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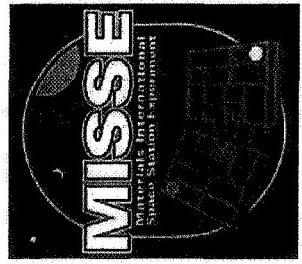


Total Loss and Calorimetry at 1064nm

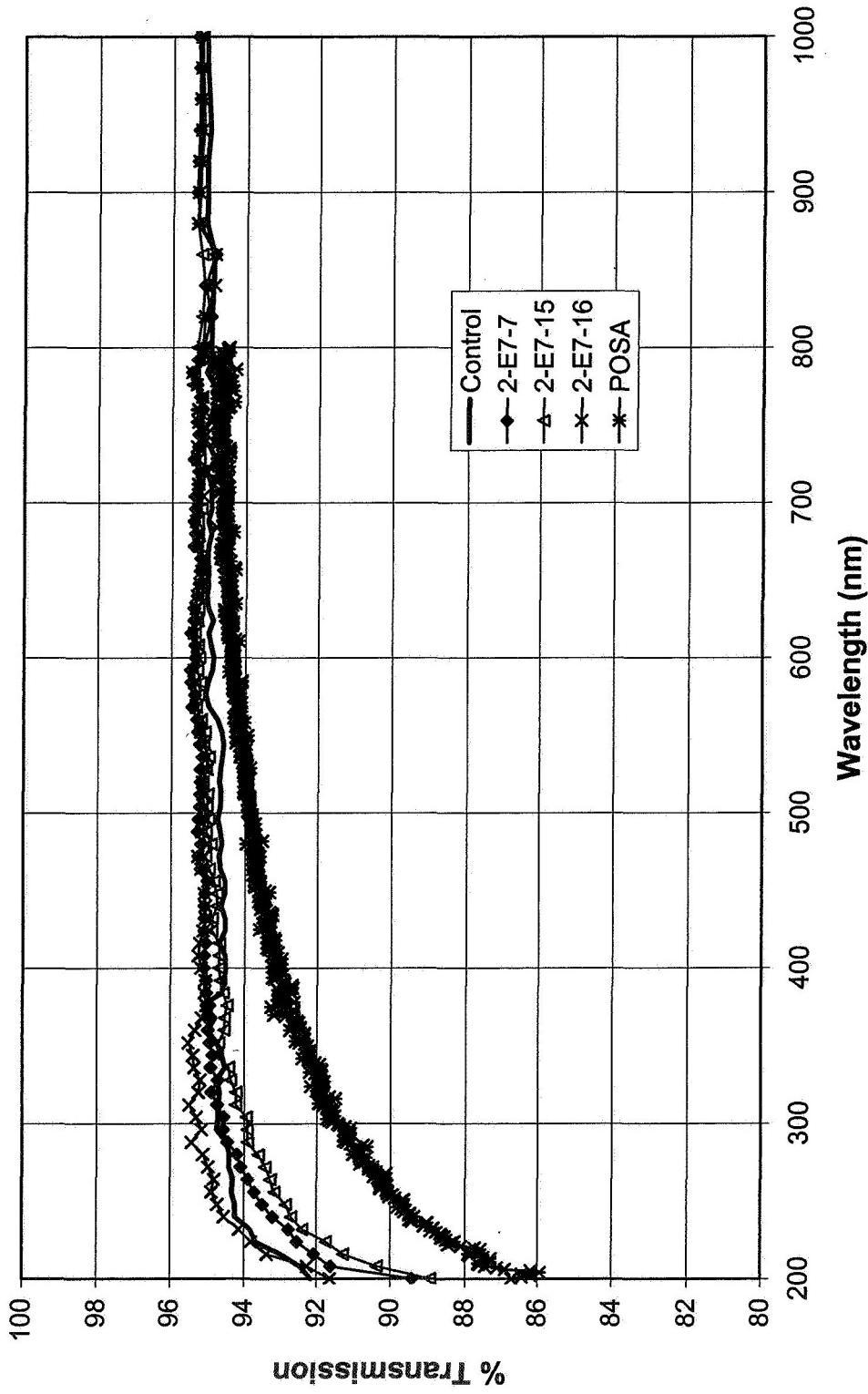


MgF₂ Windows Show Effects of Space





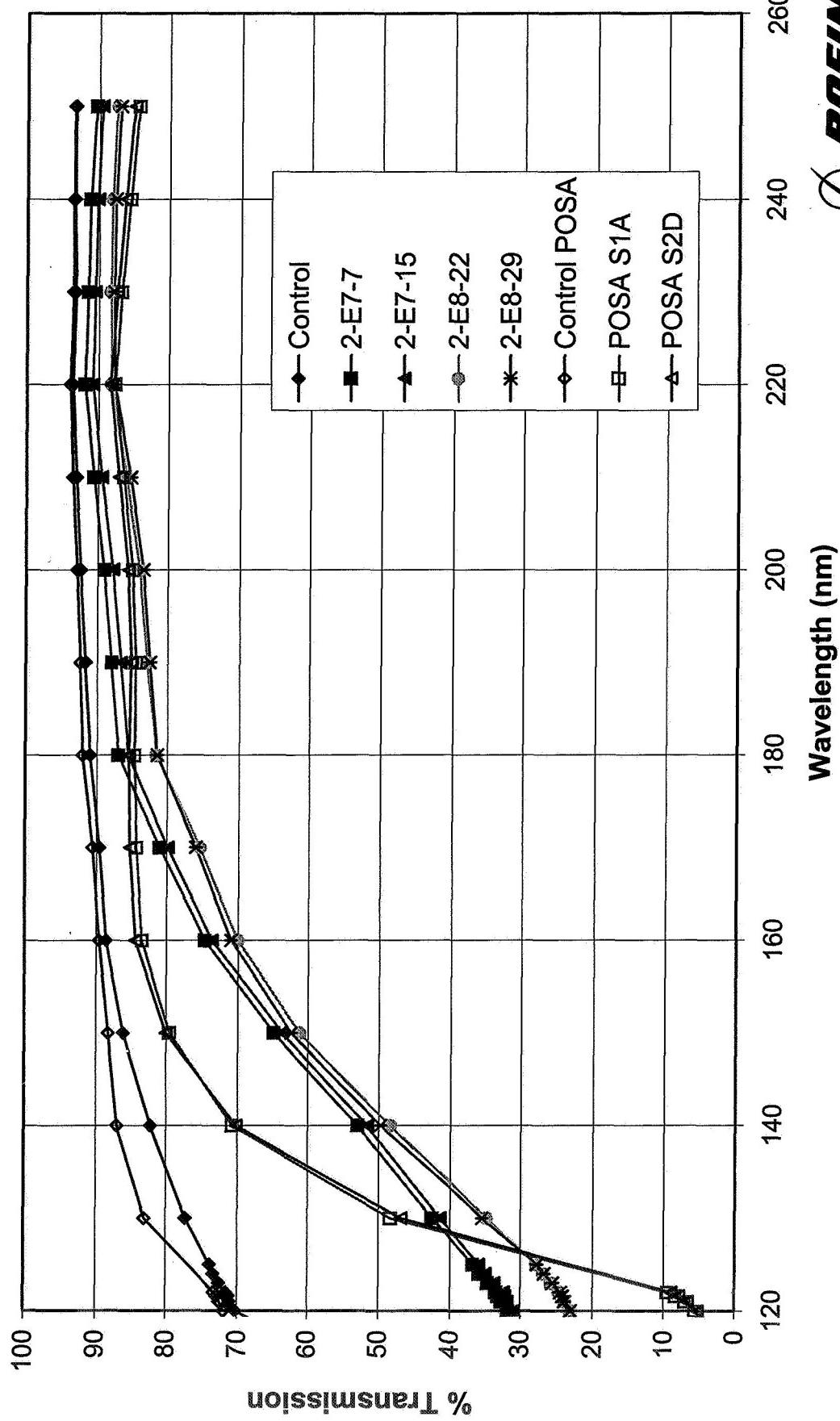
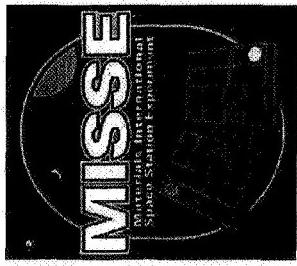
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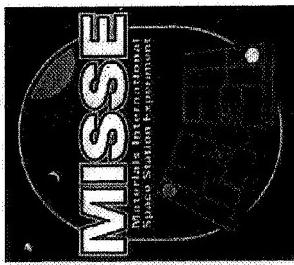
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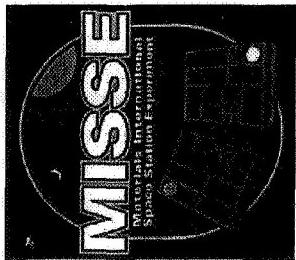
MISSE MgF₂ Windows Comparison with POSA



Summary



- Flight samples experienced some mechanical damage from contact with the surface of the tray.
- Contamination was present on all samples
 - Increased total loss
 - Light scatter
 - Haze
 - Particulate or isolated defects were present on all samples
- Absorption increased on flight samples by factor > 2X
- Total loss increased on Flight samples by factor > 3X
- Overall sample performance better than was hoped for



MISSE has a Bright Future !

Continuing study of samples on the ground

- Evaluation of contamination layer and surfaces
- Scatter maps to show distribution and magnitude of “defects”
- MISSE 3,4 deployed July 06 (1 yr)
- MISSE 6 in integration
- MISSE 7 in planning stages